Laporan Tugas Besar 1 IF3270 Pembelajaran Mesin

Bagian B

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Daftar Isi

Penjelasan Implementasi

Neural Network merupakan sebuah metode kecerdasan buatan yang mengajarkan komputer untuk memproses data dengan cara yang terinspirasi oleh otak manusia. Dalam *machine learning*, *neural network* mengacu pada sekumpulan algoritma yang di *design* untuk membantu mesin dalam menemukan pattern tanpa diprogram secara eksplisit. Dalam neural network terdapat tiga hal dasar, yaitu *input layer*, *hidden layer*, dan *output layer*.

Pada kali ini, dirancang algoritma untuk melakukan *backpropagation* dari modul *feed forward* yang menerima input yang dalam bentuk file JSON dengan memanfaatkan beberapa *library* yang terdapat pada Python, seperti numpy untuk melakukan perhitungan, json untuk load model dari file JSON. Berikut adalah turunan fungsi aktivasi dan fungsi loss yang diimplementasikan.

Untuk turunan ReLU jika $x < 0$ maka $\frac{d}{dx}ReLU(x) = 0$, jika $x \geq 0$ $\frac{d}{dx}ReLU(x) = 1$.

Untuk turunan Sigmoid $\frac{d}{dx}\sigma(x) = \sigma(x) \times (1 - \sigma(x))$.

Untuk turunan Linear $\frac{d}{dx}x = 1$.

Untuk turunan Softmax jika $j \neq target$ maka $\frac{\partial E_d}{\partial net(x)} = p_j$, jika $j = target$ maka $\frac{\partial E_d}{\partial net(x)} = -(1 - p_j)$.

Untuk ReLU, sigmoid, dan linear memiliki fungsi loss $E = \frac{1}{2}\sum_{k \epsilon output}(t_k - o_k)^2$.

Untuk Softmax memiliki fungsi loss $E = -log(p_k),\ k = target.$

Proses Implementasi dimulai dari fungsi pembacaan file csv dan json pada fungsi readCSV akan menghasilkan output `id_list, sepal_length_list, sepal_width_list, petal_length_list, petal_width_list, species_list.` Fungsi readJSON akan menghasilkan output `input_size, layer, weights, input_array, target, learning_rate, batch_size, max_iteration, error_threshold, num_layer.`

```
class fileSystem:
   @staticmethod
   def readCSV(filename):
       id_list = []
       sepal_length_list = []
       sepal_width_list = []
       petal_length_list = []
       petal_width_list = []
       species_list = []
       with open(filename + '.csv', 'r') as csv_file:
           csv_reader = csv.reader(csv_file)
           next(csv_reader)
           for row in csv_reader:
               id = row[0]
               sepal_length = row[1].split(',')
               sepal_width = row[2].split(',')
               petal_length = row[3].split(',')
               petal_width = row[4].split(',')
               species = row[5].split(',')

               id_list.append(id)
               sepal_length_list.append(sepal_length)
               sepal_width_list.append(sepal_width)
               petal_length_list.append(petal_length)
               petal_width_list.append(petal_width)
               species_list.append(species)

       return id_list, sepal_length_list, sepal_width_list, petal_length_list,
petal_width_list, species_list

   def readJSON(filename):
       with open("testcaseB/" + filename + ".json", 'r') as file:
           data = json.load(file)
           input_size = data["case"]["model"]["input_size"]
           layer = data["case"]["model"]["layers"]
           weights = data["case"]["initial_weights"]
           input_array = np.array(data["case"]["input"])
           target = np.array(data["case"]["target"])
           learning_rate = data["case"]["learning_parameters"]["learning_rate"]
           batch_size = data["case"]["learning_parameters"]["batch_size"]
           max_iteration = data["case"]["learning_parameters"]["max_iteration"]
           error_threshold = data["case"]["learning_parameters"]["error_threshold"]
           num_layer = len(layer)

       return input_size, layer, weights, input_array, target, learning_rate, batch_size,
max_iteration, error_threshold, num_layer
```

Selanjutnya dibuat kelas forwardActivation untuk membuat fungsi aktivasi forward.

```
class forwardActivation:
   def relu(x):
       return np.maximum(0,x)
   def sigmoid(x):
       return 1 / (1 + np.exp(-x))
   def linear(x):
       return x
   def softmax(x):
       return np.exp(x) / np.sum(np.exp(x))
```

Selanjutnya dibuat kelas backActivationOutput untuk membuat fungsi aktivasi back pada output layer.

```
class backActivationOutput:
   def relu(x):
       if x >= 0:
           return 1
       else:
           return 0
   def linear(x):
       return 1
   def sigmoid(x):
       return x*(1 - x)
   def softmax(x):
       return 0
```

Selanjutnya dibuat kelas backActivationHiddem untuk membuat fungsi aktivasi back pada hidden layer.

```
class backActivationHidden:
    def relu(x, y):
        if x >= 0:
            return -(x-y)
        else:
            return 0
    def linear(x, y):
        return -(x-y)
    def sigmoid(x, y):
        return -y * (1-y) * (x-y)
    def softmax(a, b, x: int, y: int):
        return b if (x != y) else (-1 * (1 - a))
```

Selanjutnya dibuat kelas Layer untuk inisialisasi layer.

```
class Layer:
   def __init__(self, neurons, activation, weights=None, bias=1):
       self.neurons = neurons
       self.activation_name = activation
       self.activation_func = forwardActivation.__dict__[activation]
       self.activation_derivative_output = backActivationOutput.__dict__[activation]
       self.activation_derivative_hidden = backActivationHidden.__dict__[activation]
       self.weights = weights
       self.bias = bias
       self.outputs = None  # Initialize outputs attribute to None

   def set_outputs(self, outputs):
       self.outputs = outputs
```

Selanjutnya terdapat kelas NeuralNetwork, yang berisi add_layer untuk penambahan layer, forward_pass untuk forward propagation, calculate_loss untuk menghitung loss, backward_pass untuk backward propagation, train untuk training dataset, addLayer untuk perbandingan, save_model untuk menyimpan model ke dalam pickle, dan load_model untuk load model dari pickle.

```
class NeuralNetwork:
    def __init__(self, learning_rate=0.1, batch_size=10, max_iterations=100, 
error_threshold=0.1):
        self.layers = []
        self.learning_rate = learning_rate
        self.batch_size = batch_size
        self.max_iteration = max_iterations
        self.error_threshold = error_threshold

    def add_layer(self, num_neurons, activation_function, weights, bias):
        self.layers.append(Layer(
            neurons=num_neurons,
            activation=activation_function,
            weights=weights,
            bias=bias,
        ))

    def forward_pass(self, input_array):
        outputs = input_array
        for i, layer in enumerate(self.layers):
            layer_output = layer.activation_func(np.dot(outputs, layer.weights) + layer.bias)
            layer.set_outputs(layer_output)  # Set outputs attribute
            outputs = layer_output
        return outputs

    def calculate_loss(self, outputs, targets):
        return np.mean(np.square(targets - outputs))

    def backward_pass(self, input_array, targets, outputs):
        delta = -(targets - outputs) * self.layers[-1].activation_derivative_output(outputs)
        for i in range(len(self.layers) - 1, -1, -1):
            layer = self.layers[i]

            if i != 0:
                delta_weights = np.dot(self.layers[i - 1].outputs.T, delta)
            else:
                delta_weights = np.dot(input_array.T, delta)
            layer.weights -= self.learning_rate * delta_weights

            delta_bias = np.sum(delta, axis=0)
            layer.bias -= self.learning_rate * delta_bias

            if i > 0:
                delta = np.dot(delta, self.layers[i].weights.T) *
self.layers[i].activation_derivative_hidden(self.layers[i - 1].outputs, outputs)

    def train(self, input_array, targets):
        for epoch in range(self.max_iteration):
            for i in range(0, len(input_array), self.batch_size):
                input_batch = input_array[i:i + self.batch_size]
                target_batch = targets[i:i + self.batch_size]

                # Forward pass for the entire batch
                outputs = self.forward_pass(input_batch)

                # Backward pass for the entire batch
                self.backward_pass(input_batch, target_batch, outputs)

                # Calculate loss for the entire batch
                loss = self.calculate_loss(outputs, target_batch)

                print(f"Iteration {epoch + 1}, Loss: {loss}")

                # Check for early stopping
                if loss < self.error_threshold:
                    print("Training converged: Error threshold reached.")
                    return
            if epoch == self.max_iteration - 1:
                print("Training stopped by max iteration.")

        print("Final Weights:")
        for i, layer in enumerate(self.layers):
            print(f"Layer {i+1}:")
            print(layer.bias)
            print(layer.weights)

    def addLayer(self, layer: Layer) -> None:
        if self.layers:
            layer.input_shape = self.layers[-1].output_shape
        self.layers.append(layer)

    def save_model(self, filename):
        with open(filename, 'wb') as f:
            pickle.dump(self, f)

    def load_model(filename):
        with open(filename, 'rb') as f:
            return pickle.load(f)
```

```
iris = load_iris()
X_iris = iris.data
y_iris = iris.target

X_train, X_val, y_train, y_val = train_test_split(X_iris, y_iris, test_size=0.3,
random_state=42)

model_iris_sklearn = MLPClassifier(hidden_layer_sizes=(4,), activation="logistic",
learning_rate_init=0.1,
                                   batch_size=10, max_iter=1000, solver="sgd", random_state=42)
model_iris_sklearn.fit(X_train, y_train)
predictions_sklearn = model_iris_sklearn.predict(X_val)

report_sklearn = classification_report(y_val, predictions_sklearn)

mlp_custom = NeuralNetwork(learning_rate=0.1, max_iterations=1000, batch_size=10,
error_threshold=0.01)
mlp_custom.addLayer(Layer(input_shape=X_train.shape[1], neurons=4, activation='sigmoid'))
mlp_custom.addLayer(Layer(neurons=3, activation='linear'))  # Output layer
```

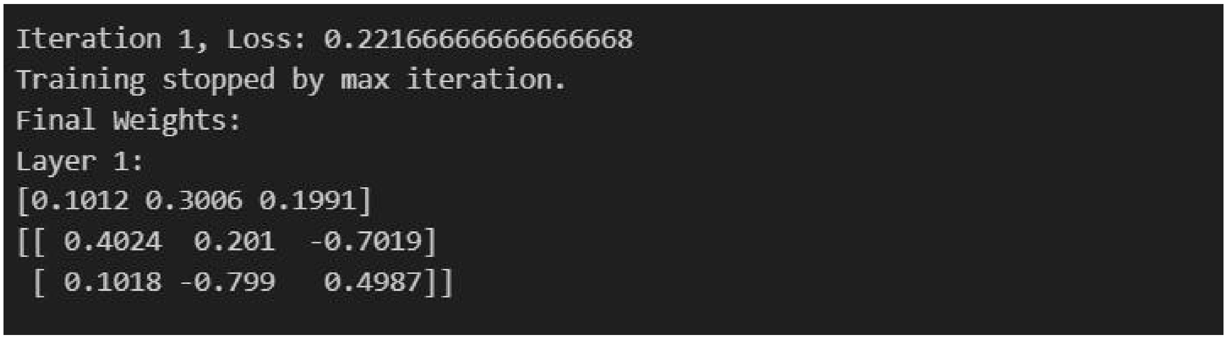
```
y_train_onehot = np.eye(3)[y_train]
stop_reason = mlp_custom.fit(X_train, y_train_onehot)

predictions_custom = np.argmax(mlp_custom.predict(X_val), axis=1)

report_custom = classification_report(y_val, predictions_custom)
```

Hasil Pengujian

Setelah melakukan perancangan algoritma, dilakukan pengujian untuk setiap hasil test case yang telah diberikan. Berikut adalah hasil pengujian dari setiap test case.

1. Linear

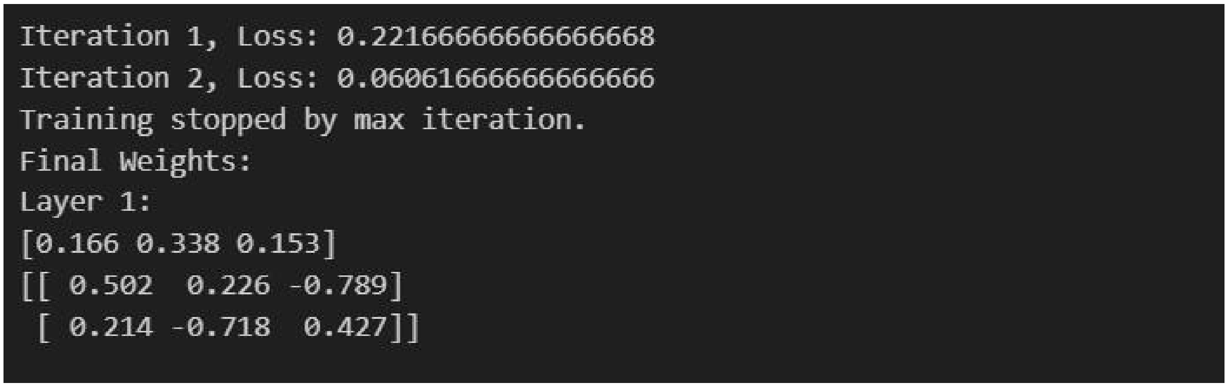
Hasil Pengujian



```
Iteration 1, Loss: 0.22166666666666668
Training stopped by max iteration.
Final Weights:
Layer 1:
[0.1012 0.3006 0.1991]
[[ 0.4024  0.201  -0.7019]
 [ 0.1018 -0.799   0.4987]]
```

2. Linear Two Iteration

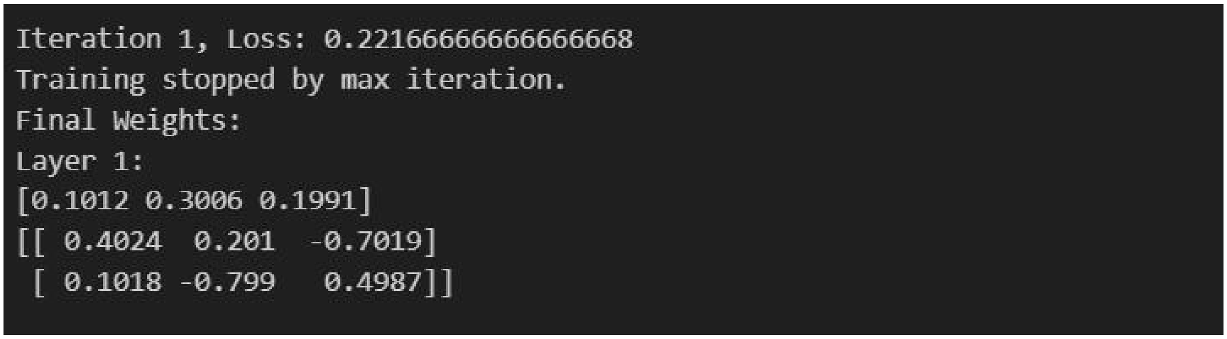
Hasil Pengujian



```
Iteration 1, Loss: 0.22166666666666668
Iteration 2, Loss: 0.06061666666666666
Training stopped by max iteration.
Final Weights:
Layer 1:
[0.166 0.338 0.153]
[[ 0.502  0.226 -0.789]
 [ 0.214 -0.718  0.427]]
```

3. Linear Small LR

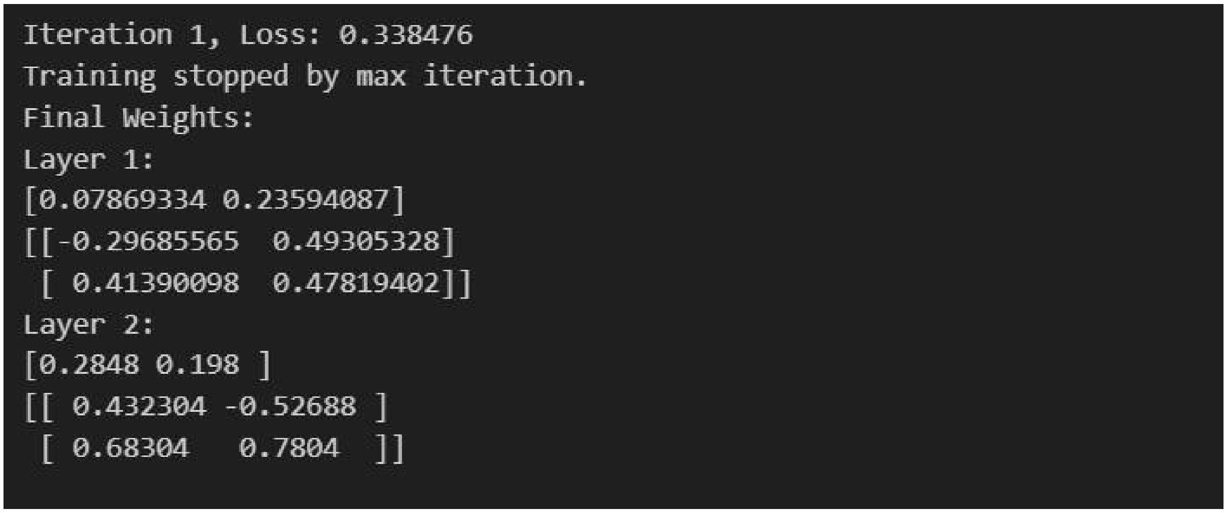
Hasil Pengujian



```
Iteration 1, Loss: 0.22166666666666668
Training stopped by max iteration.
Final Weights:
Layer 1:
[0.1012 0.3006 0.1991]
[[ 0.4024  0.201  -0.7019]
 [ 0.1018 -0.799   0.4987]]
```

4. MLP

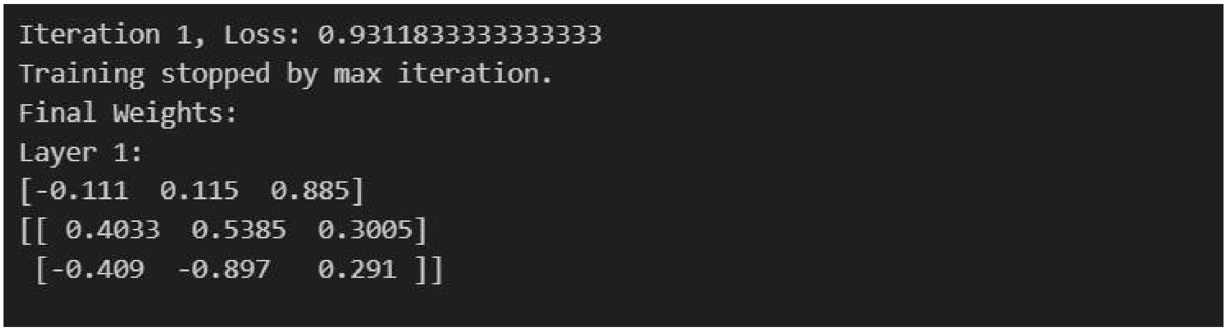
Hasil Pengujian



```
Iteration 1, Loss: 0.338476
Training stopped by max iteration.
Final Weights:
Layer 1:
[0.07869334 0.23594087]
[[-0.29685565  0.49305328]
 [ 0.41390098  0.47819402]]
Layer 2:
[0.2848 0.198 ]
[[ 0.432304 -0.52688 ]
 [ 0.68304   0.7804  ]]
```

5. Relu B

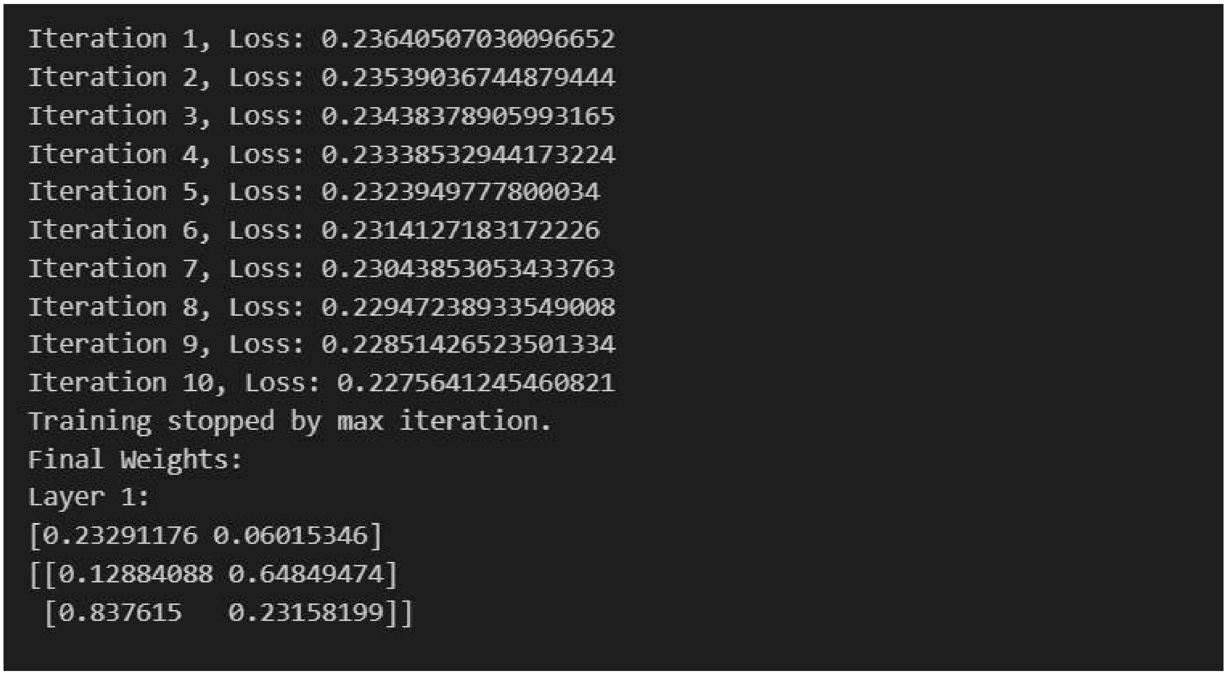
Hasil Pengujian



```
Iteration 1, Loss: 0.9311833333333333
Training stopped by max iteration.
Final Weights:
Layer 1:
[-0.111  0.115  0.885]
[[ 0.4033  0.5385  0.3005]
 [-0.409  -0.897   0.291 ]]
```

6. Sigmoid

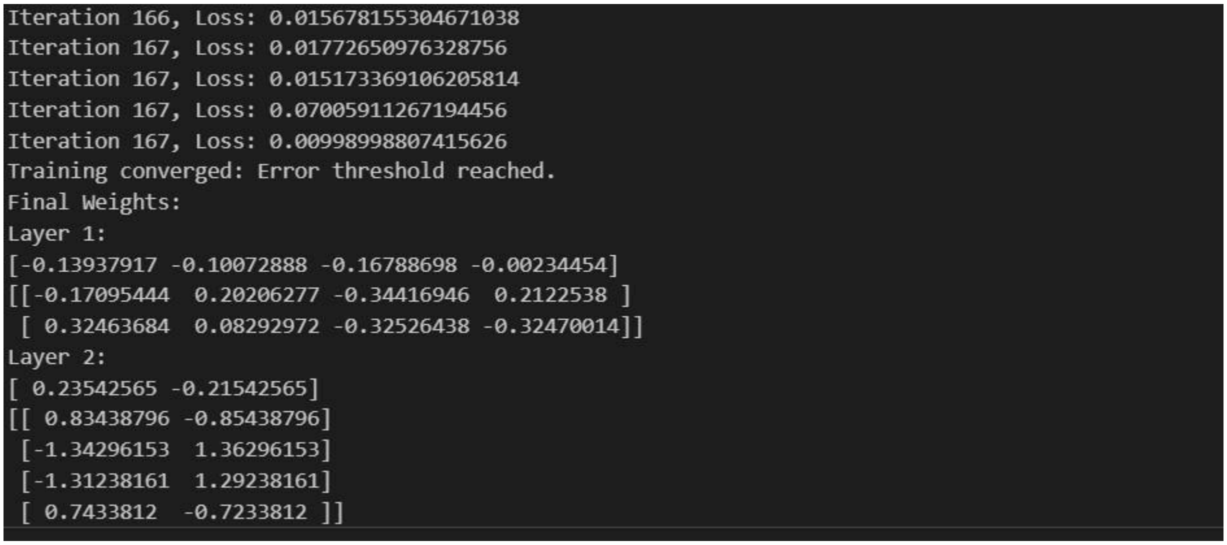
Hasil Pengujian



```
Iteration 1, Loss: 0.23640507030096652
Iteration 2, Loss: 0.23539036744879444
Iteration 3, Loss: 0.23438378905993165
Iteration 4, Loss: 0.23338532944173224
Iteration 5, Loss: 0.2323949777800034
Iteration 6, Loss: 0.2314127183172226
Iteration 7, Loss: 0.23043853053433763
Iteration 8, Loss: 0.22947238933549008
Iteration 9, Loss: 0.22851426523501334
Iteration 10, Loss: 0.2275641245460821
Training stopped by max iteration.
Final Weights:
Layer 1:
[0.23291176 0.06015346]
[[0.12884088 0.64849474]
 [0.837615   0.23158199]]
```

7. Softmax Two Layer

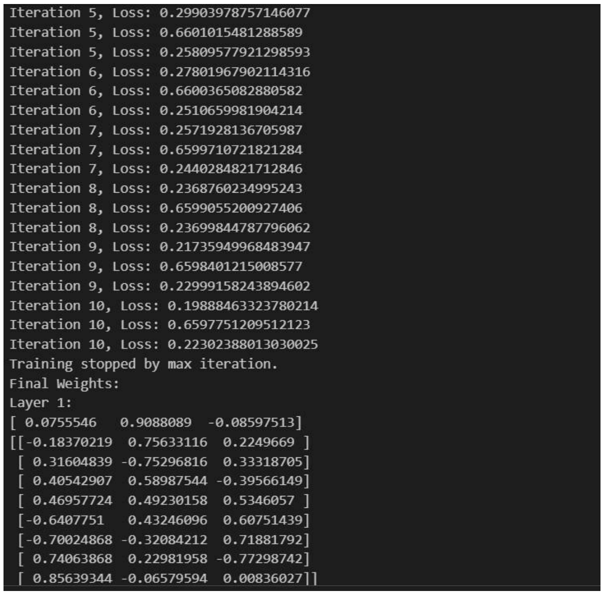
Hasil Pengujian



```
Iteration 166, Loss: 0.015678155304671038
Iteration 167, Loss: 0.01772650976328756
Iteration 167, Loss: 0.015173369106205814
Iteration 167, Loss: 0.07005911267194456
Iteration 167, Loss: 0.00998998807415626
Training converged: Error threshold reached.
Final Weights:
Layer 1:
[-0.13937917 -0.10072888 -0.16788698 -0.00234454]
[[-0.17095444  0.20206277 -0.34416946  0.2122538 ]
 [ 0.32463684  0.08292972 -0.32526438 -0.32470014]]
Layer 2:
[ 0.23542565 -0.21542565]
[[ 0.83438796 -0.85438796]
 [-1.34296153  1.36296153]
 [-1.31238161  1.29238161]
 [ 0.7433812  -0.7233812 ]]
```

8. Softmax

Hasil Pengujian



```
Iteration 5, Loss: 0.29903978757146077
Iteration 5, Loss: 0.6601015481288589
Iteration 5, Loss: 0.25809577921298593
Iteration 6, Loss: 0.27801967902114316
Iteration 6, Loss: 0.6600365082880582
Iteration 6, Loss: 0.2510659981904214
Iteration 7, Loss: 0.2571928136705987
Iteration 7, Loss: 0.6599710721821284
Iteration 7, Loss: 0.2440284821712846
Iteration 8, Loss: 0.2368760234995243
Iteration 8, Loss: 0.6599055200927406
Iteration 8, Loss: 0.23699844787796062
Iteration 9, Loss: 0.21735949968483947
Iteration 9, Loss: 0.6598401215008577
Iteration 9, Loss: 0.22999158243894602
Iteration 10, Loss: 0.19888463323780214
Iteration 10, Loss: 0.6597751209512123
Iteration 10, Loss: 0.22302388013030025
Training stopped by max iteration.
Final Weights:
Layer 1:
[ 0.0755546   0.9088089  -0.08597513]
[[-0.18370219  0.75633116  0.2249669 ]
 [ 0.31604839 -0.75296816  0.33318705]
 [ 0.40542907  0.58987544 -0.39566149]
 [ 0.46957724  0.49230158  0.5346057 ]
 [-0.6407751   0.43246096  0.60751439]
 [-0.70024868 -0.32084212  0.71881792]
 [ 0.74063868  0.22981958 -0.77298742]
 [ 0.85639344 -0.06579594  0.00836027]]
```

Pembagian Tugas

NIM	Nama	Tugas
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13521013	Eunice Sarah Siregar	Membuat Backpropagation
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